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HIGH SPECTRAL RESOLUTION REMOTE SENSING OF CANOPY CHEMISTRY

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1 INTRODUCTION

Near infrared laboratory spectra have been used for many years to determine nitrogen and lignin concentrations in plant materials (Norris *et al.* 1976; Wessman *et al.* 1988a). In recent years, similar high spectral resolution visible and infrared data have been available via airborne remote sensing instruments. Using data from NASA's Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) we attempt to identify spectral regions correlated with foliar chemistry at the canopy level in temperate forests.

2 METHODS

Two well-studied research sites were used for this study. Harvard Forest is a 1200 hectare research site in central Massachusetts, USA (Latitude 42°32'N Longitude 72°11'W) containing a combination of hardwood and mixed hardwood/conifer stands as well as several plantations of pine, spruce and larch. Blackhawk Island in south-central Wisconsin, USA (Latitude 43°40'N Longitude 89°45'W), is a natural area containing a wide diversity of forest types including maple, oak, pine and hemlock.

Field data were collected for 20 plots at each site within 10 days of the acquisition of remote sensing data. Fresh leaf samples were collected from five trees of each overstory species in each plot. Nitrogen concentrations in all samples were determined by CHN analysis and lignin by a sequential extraction/sulfuric acid digestion procedure (McClaugherty and Berg 1987). Litterfall collections, sorted by species, were used to determine the relative canopy biomass of each species. Total canopy nitrogen and lignin concentrations were calculated as mean concentration per species weighted by foliar mass per species.

Remote sensing data were acquired using AVIRIS on 15 June 1992 at Harvard Forest and 21 June 1992 at Blackhawk Island. AVIRIS records data in 224 contiguous spectral bands covering the spectral range of 400 - 2500nm with a spectral resolution of 10nm and spatial resolution of 20m (Vane *et al.* 1988). Atmospheric corrections of the AVIRIS data were done by the ATREM program (Gao *et al.* 1992). This program uses information in each AVIRIS radiance spectra to parameterize a radiative transfer model that is then used to convert radiance data to ground reflectance by removing the effects of atmospheric gases, water vapor and aerosols. In addition to the ATREM correction, a secondary correction was made based on the difference between a ground calibrated Blackhawk Island scene and the same ATREM corrected scene (Clark *et al.* 1993)(personal communication, K. Heidebrecht).

Atmospherically corrected AVIRIS data were transformed to first difference spectra. The mean of the first difference spectra from a 2x2 array of pixels overlapping each of the 40 field locations was used in this analysis.

3 RESULTS

Data from both Harvard Forest and Blackhawk Island were combined for lignin and nitrogen calibrations. Validations of the calibration equations were assessed by an iterative cross-validation method in which each sample in turn was dropped from the calibration process and predicted from the resulting equation (Mark and Workman 1991). Canopy nitrogen concentrations were predicted from first difference AVIRIS spectra using equation 1:

$$\%Nitrogen = 0.486 + (0.001 * 783nm) + (0.003 * 1640nm) \quad (1)$$

The relationship between field measured and AVIRIS predicted nitrogen for the forty plots is shown in figure 1a. Absorption at 764*nm* corresponds with both a third overtone N-H absorption feature and a chlorophyll absorption feature (Gates *et al.* 1965). Chlorophyll content in foliage is highly correlated with total protein, and hence total nitrogen content. 1640*nm* is a first overtone of a C-H absorption band (Murray and Williams 1987).

Similarly, canopy lignin concentrations were predicted with equation 2 using four bands of the first difference absorption spectra:

$$\%Lignin = 33.36 - (0.048*822nm) + (0.106*627nm) + (0.005*756nm) + (0.052*1660nm) \quad (2)$$

Absorption at 1660*nm* is related to absorption overtones of unsaturated or phenolic C-C bonds which are abundant in lignin molecules (Murray and Williams 1987). The three shorter wavelengths used in this equation correspond to a region of high absorbance observed in the laboratory spectra of lignin. Figure 1b shows the relationship between field measured and AVIRIS predicted lignin concentrations. Figures 2a and 3a shows the AVIRIS predicted nitrogen and lignin concentrations for each pixel in the Harvard Forest and Blackhawk Island scenes, respectively.

Previous research at Blackhawk Island has demonstrated a very strong ($R^2 = .96, n = 7, p < .001$) relationship between canopy lignin concentration and annual net nitrogen mineralization, or nitrogen cycling (Wessman *et al.* 1988b). This relationship has been used with remote sensing data from a low-elevation airborne platform to produce a verified map of nitrogen mineralization for Blackhawk Island (Wessman *et al.* 1988b). A nearly identical map is generated from an image of estimated lignin concentrations from 1992 AVIRIS data (Figure 3b).

At the Harvard Forest, a simple model of monthly carbon balances driven largely by foliar nitrogen concentrations, has been validated against monthly carbon balance data obtained by eddy-correlation methods (Aber and Federer 1992). Applying this model to an image of foliar nitrogen concentrations at the Harvard Forest, yields an estimate of net ecosystem exchange of carbon for the entire research site (Figure 2b).

These results demonstrate the potential for high resolution remote sensing to increase both the accuracy of spatially averaged estimates of carbon and nitrogen cycling in temperate forest ecosystems, and to increase the spatial detail of those estimates.

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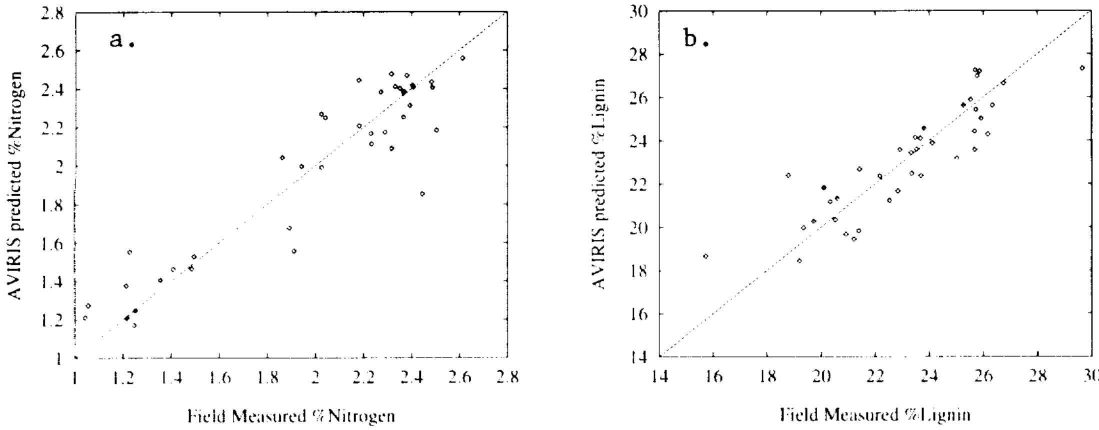

Figure 1: AVIRIS predicted vs field measured nitrogen (a) and lignin (b) - Blackhawk Island and Harvard Forest Sites combined.

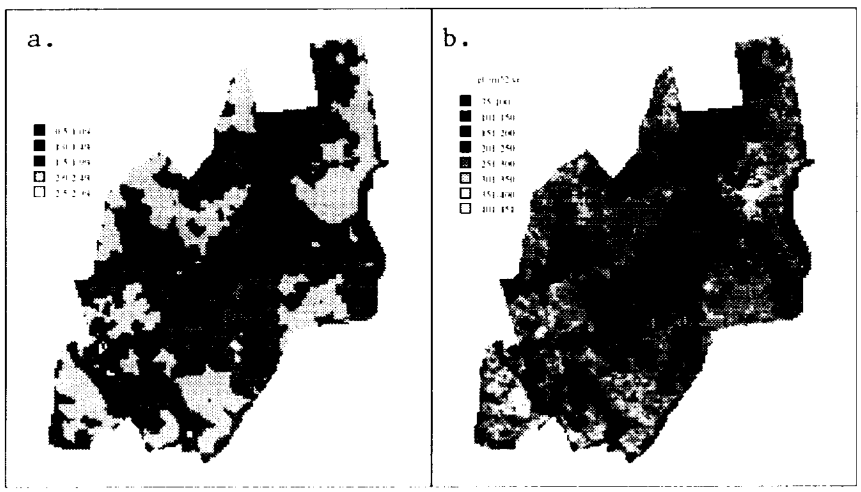

Figure 2: Harvard Forest - a. percent canopy nitrogen as calculated with AVIRIS data (equation 1). b. net ecosystem productivity predicted using AVIRIS derived nitrogen as a model input parameter.

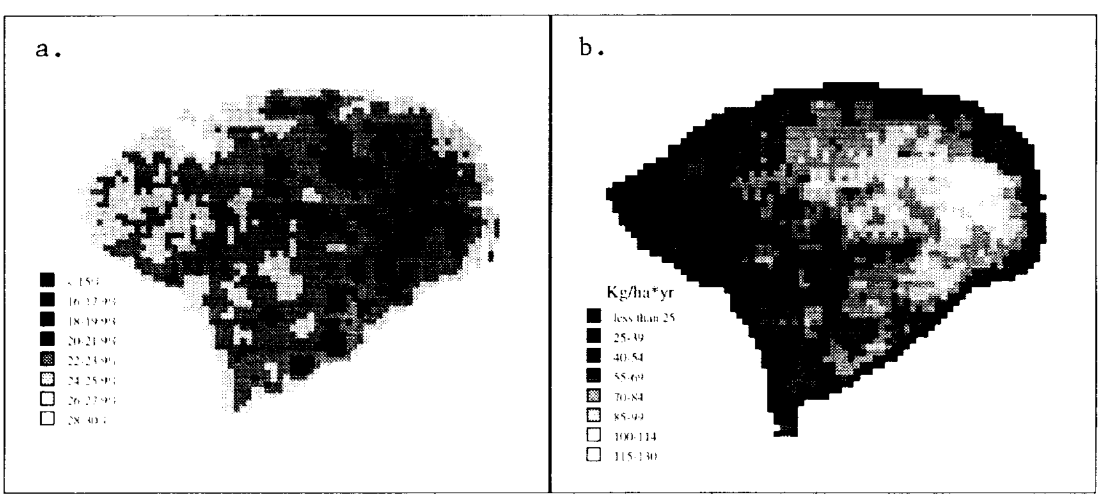

Figure 3: Blackhawk Island - a. percent canopy lignin as calculated with AVIRIS data (equation 2) b. nitrogen mineralization rate.